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National Eutrophication Survey, Corvallis, Oreg

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REPORT

ON

LAKE TAWAKONI

HUNT, RAINS, AND VAN ZANDT COUNTIES

TEXAS

EPA REGION VI

WORKING PAPER NO. 662

WITH THE COOPERATION OF THE

TEXAS WATER QUALITY BOARD

AND THE

TEXAS NATIONAL GUARD

APRIL, 1977

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16. ABSTRACT

Annual total phosphorus and total nitrogen loadings to the lake were estimated and subdivided according to either point or non-point source origin. An assessment of the lake's trophic condition and limiting nutrient is also provided. All data collected by the U.S.E.P.A. National Eutrophication Survey during the one year study of the lake and its tributaries are included in the report.

17. KEY WORDS AND DOCUMENT ANALYSIS

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FOREWORD

The National Eutrophication Survey was initiated in 1972 in response to an Administration commitment to investigate the nationwide threat of accelerated eutrophication to freshwater lakes and reservoirs.

OBJECTIVES

The Survey was designed to develop, in conjunction with state environmental agencies, information on nutrient sources, concentrations, and impact on selected freshwater lakes as a basis for formulating comprehensive and coordinated national, regional, and state management practices relating to point-source discharge reduction and non-point source pollution abatement in lake watersheds.

ANALYTIC APPROACH

The mathematical and statistical procedures selected for the Survey's eutrophication analysis are based on related concepts that:

a. A generalized representation or model relating sources, concentrations, and impacts can be constructed.

b. By applying measurements of relevant parameters associated with lake degradation, the generalized model can be transformed into an operational representation of a lake, its drainage basin, and related nutrients.

c. With such a transformation, an assessment of the potential for eutrophication control can be made.

LAKE ANALYSIS

In this report, the first stage of evaluation of lake and watershed data collected from the study lake and its drainage basin is documented. The report is formatted to provide state environmental agencies with specific information for basin planning [§303(e)], water quality criteria/standards review [§303(c)], clean lakes [§314(a,b)], and water quality monitoring [§106 and §305(b)] activities mandated by the Federal Water Pollution Control Act Amendments of 1972.

Beyond the single lake analysis, broader based correlations between nutrient concentrations (and loading) and trophic condition are being made to advance the rationale and data base for refinement of nutrient water quality criteria for the Nation's fresh water lakes. Likewise, multivariate evaluations for the relationships between land use, nutrient export, and trophic condition, by lake class or use, are being developed to assist in the formulation of planning guidelines and policies by EPA and to augment plans implementation by the states.

ACKNOWLEDGEMENT

The staff of the National Eutrophication Survey (Office of Research & Development, U. S. Environmental Protection Agency) expresses sincere appreciation to the Texas Water Quality Board for professional involvement, to the Texas National Guard for conducting the tributary sampling phase of the Survey, and to those Texas wastewater treatment plant operators who voluntarily provided effluent samples.

Hugh C. Yantis, Jr., Executive Director of the Texas Water Quality Board, and John B. Latchford, Jr., Director, and the staff of the Field Operations Division provided invaluable lake documentation and counsel during the Survey, reviewed the preliminary reports, and provided critiques most useful in the preparation of this Working Paper series.

Major General Thomas Bishop, the Adjutant General of Texas, and Project Officer Colonel William L. Seals, who directed the volunteer efforts of the Texas National Guardsmen, are also gratefully acknowledged for their assistance to the Survey.

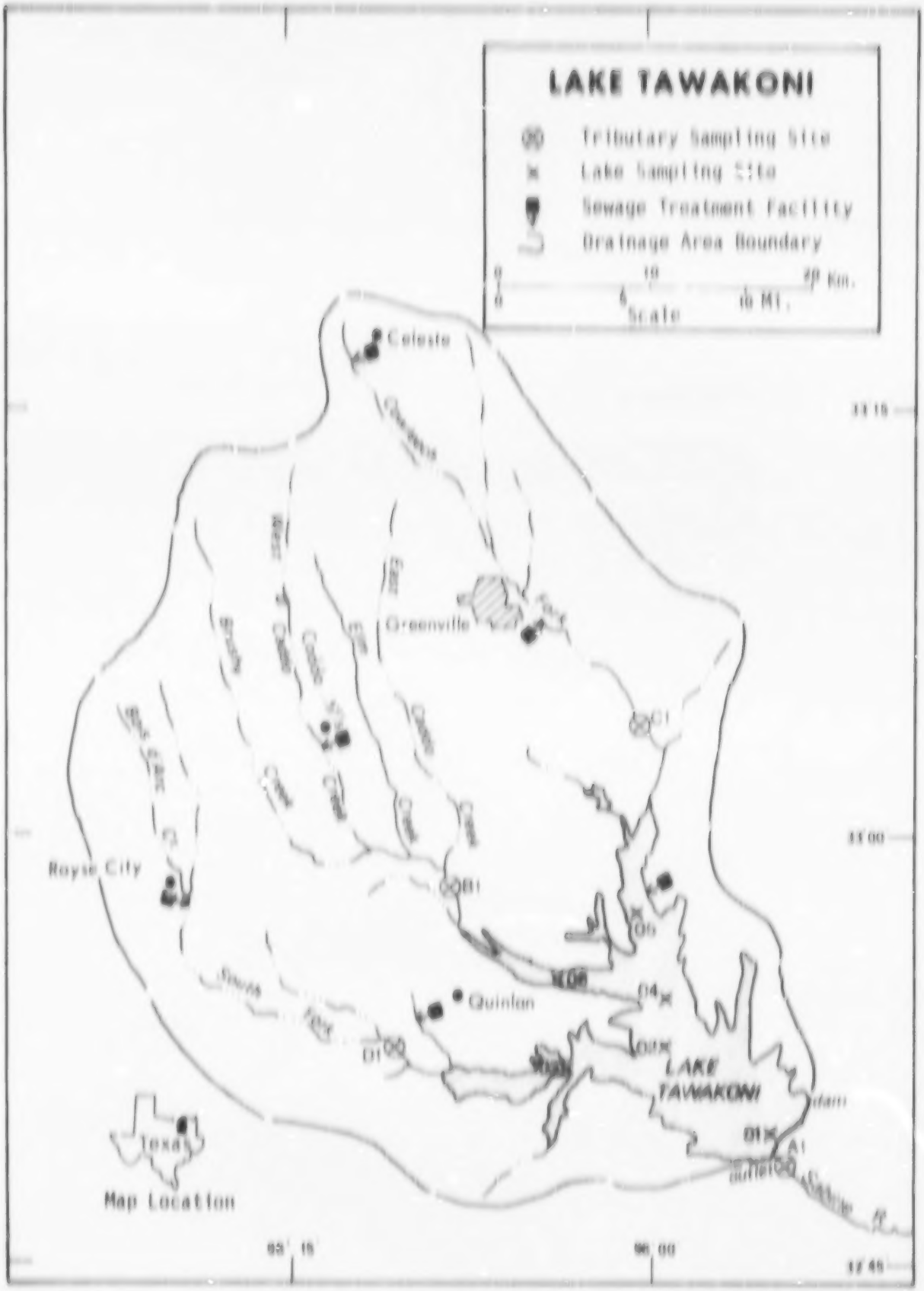
NATIONAL EUTROPHICATION SURVEY

STUDY RESERVOIRS

State of Texas

NAME	COUNTY
Amistad	Val Verde
Bastrop	Bastrop
Belton	Bell, Coryell
Braunig	Bexar
Brownwood	Brown
Buchanan	Burnet, Llano
Caddo	Harrison, Marion, TX; Caddo Parish, LA
Calaveras	Bexar
Canyon	Comal
Colorado City	Mitchell
Corpus Christi	Jim Wells, Live Oak, San Patricio
Diversion	Archer, Baylor
Eagle Mountain	Tarrant, Wise
Fort Phantom Hill	Jones
Houston	Harris
Kemp	Baylor
Lake O'The Pines	Camp, Marion, Morris, Upshur
Lavon	Collin
Lewisville (Garza-Little Elm)	Denton
Livingston	Polk, San Jacinto, Trinity, Walker

Lyndon B. Johnson	Burnet, Llano
Medina	Bandera, Medina
Meredith	Hutchinson, Moore, Potter
O. C. Fisher (San Angelo)	Tom Green
Palestine	Anderson, Cherokee, Henderson, Smith
Possum Kingdom	Palo Pinto, Stephens, Young
Sam Rayburn	Angelina, Jasper Nacogdoches, Sabine, San Augustine
Somerville	Burleson, Lee, Washington
E. V. Spence	Coke
Stamford	Haskell
Stillhouse Hollow	Bell
Tawakoni	Hunt, Rains, Van Zandt
Texoma	Cooke, Grayson TX; Bryan, Johnston, Love, Marshall, OK
Travis	Burnet, Travis
Trinidad	Henderson
Twin Buttes	Tom Green
White River	Crosby
Whitney	Bosque, Hill
Wright Patman (Texarkana)	Bowie, Cass


LAKE TAWAKONI
Tributary Sampling Site
Lake Sampling Site
Sewage Treatment Facility
Drainage Area Boundary
0 10 20 Km.
0 5 10 Mi.
Scale
Celeste
Greenville
Royse City
Quinlan
LAKE TAWAKONI
Dam
Texas
Map Location
33 15
33 00
32 45
96 00
95 45

LAKE TAWAKONI

STORET NO. 4837

I. CONCLUSIONS

A. Trophic Condition:

Survey data indicate that Lake Tawakoni is eutrophic; i.e., well supplied with nutrients and quite productive. Whether nutrient enrichment is beneficial or deleterious depends on the actual or potential effect on the uses of the lake. In this regard, no nuisance conditions are known to personnel of the Texas Water Quality Board and there is little or no impairment of the designated beneficial uses of this water body.

Lake Tawakoni ranked twenty-eighth when the 39 Texas reservoirs sampled in 1974 were compared using a combination of six parameters* as an index to overall trophic quality. Twenty-six of the reservoirs had less median total phosphorus, 25 had less and three had the same median dissolved phosphorus, 11 had less and one had the same median inorganic nitrogen, 30 had less mean chlorophyll a, and 24 had greater mean Secchi disc transparency. Marked depression of dissolved oxygen with depth occurred at station 1 in August.

Survey limnologists observed surface concentrations of algae at station 6 in March and noted the occurrence of emergent

* See Appendix A.

macrophytes in the shoreline shallows near stations 3 and 6 at that time. Blue-green algae were dominant in the August phytoplankton sample (page 9).

Water milfoil is reported to be very abundant in some places in the lake (Moczygemba, 1974), and aquatic macrophytes are a potential problem in the Cowlesch Fork embayment (Anonymous, 1974:71).

B. Rate-Limiting Nutrient:

A significant loss of phosphorus occurred in the assay samples between the time of collection (11/01/74) and the beginning of the algal assays, and the results are not representative of conditions in the lake at the time the samples were taken. The lake data indicate nitrogen limitation at all stations in March and November but phosphorus limitation at all stations, except station 5, in May.

C. Nutrient Controllability:

1. Point sources--The phosphorus contribution of the point sources considered in this report apparently amounted to 23.9% of the total phosphorus load reaching the lake during the sampling year. The City of Greenville contributed 20.9%, and five other dischargers collectively contributed 3.0% of the total load.

The present phosphorus loading of 0.91 g/m^2/yr is three times that proposed by Vollenweider (Vollenweider and Dillon, 1974) as a eutrophic loading (see page 16). While even complete

removal of phosphorus at the listed point sources probably would still leave a loading in excess of the eutrophic loading. It is likely that a high degree of phosphorus removal at the Greenville wastewater treatment plant would result in improvement in the quality of the Cowleech Fork embayment, particularly in view of the probable error in the "non-point" load of the Cowleech Fork (see below).

2. Non-point sources--It is calculated that over 76% of the total phosphorus load reaching the lake during the sampling year was contributed by non-point sources, but it is probable that the actual non-point load was less than indicated.

The Cowleech Fork apparently contributed 45% of the total phosphorus load (page 14) and had an exceptionally high export rate of 1.5 kg P/km^2 (page 16). However, the high nutrient concentrations measured at station C-1 (Appendix I) probably resulted from the relatively large amounts of Greenville effluent in the stream at that point in proportion to the total stream flow.

During the sampling year, the mean Greenville discharge was 0.101 m^3/sec, and the mean stream flow at the times the samples were taken was 0.482 m^3/sec (highest [30.299 m^3/sec] and lowest [0.003 m^3/sec] flows omitted; see Appendix C). On a yearly mean basis, then, the Greenville effluent would account for over 21% of the flow in the stream and, during dry periods, would account

for essentially all of the flow in the stream. In this regard, personnel of the Texas Water Quality Board calculated that 71% of the Cowleech Fork flow in January, 1974, was Greensville effluent (Anonymous, 1974[?]).

Therefore, the true non-point phosphorus load of the Cowleech Fork must have been much less than was measured; and, conversely, the proportion of the total load contributed by point sources must have been more that indicated above. For example, if the actual phosphorus expert rate of the Cowleech Fork was the same as the somewhat high South Fork rate (40 kg/km^2/yr), the non-point contribution of the Cowleech Fork would have been 16,780 kg, a difference of 44,335 kg; and the proportion of point-source contribution would be increased from 23.9% to 35.6% of the total load.

II. LAKE AND DRAINAGE BASIN CHARACTERISTICS[†]

A. Morphometry[††]:

1. Surface area: 146.52 kilometers^2.

2. Mean depth: 7.7 meters.

3. Maximum depth: 20.4 meters.

4. Volume: 1,143.6 x 10^6 m^3.

5. Mean hydraulic retention time: 3.2 years.

B. Tributary and Outlet:
(See Appendix C for flow data)

1. Tributaries -

Name	Drainage area (km^2)*	Mean flow (m^3/sec)*
Caddo Creek	505.0	1.79
Cowleech Fk., Sabine River	149.6	2.92
S. Fk., Sabine River	203.8	1.88
Minor tributaries & immediate drainage -	751.0	4.67
Totals	1,809.4	11.26

2. Outlets -

Diversions	0.0	1.26**
Sabine River	1,957.9	10.00
Totals	1,957.9***	11.26***

C. Precipitation****:

1. Year of sampling: 131.3 centimeters.

2. Mean annual: 109.4 centimeters.

† Table of metric conversions--Appendix B.
†† Moczygemba, 1974.
* For limits of accuracy, see working Paper No. 175, "...Survey Methods, 1973-1976".
** Gray, 1976.
*** Includes area of lake; outflow adjusted to equal sum of the inflows.
**** See Working Paper No. 175.

III. WATER QUALITY SUMMARY

Lake Tawakoni was sampled four times in 1974 by means of a pontoon-equipped Huey helicopter. Each time, samples for physical and chemical parameters were collected from two or more depths at six stations on the lake (see map, page vi). During each visit, a single depth-integrated (4.6 m or near bottom to surface) sample was composited from the stations for phytoplankton identification and enumeration; and during the November visit, two 18.9-liter depth-integrated samples were composited for algal assays. Also each time, a depth-integrated sample was collected from each of the stations for chlorophyll a analysis. The maximum depths sampled were 13.7 meters at station 1, 19.7 meters at station 2, 7.6 meters at station 3, 9.1 meters at station 4, 4.6 meters at station 5, and 3.4 meters at station 6.

The sampling results are presented in full in Appendix B and are summarized in the following table (the August nutrient samples were not preserved properly and were not analyzed).

[illegible] SUMMARY OF PHYSICAL AND CHEMICAL CHARACTERISTICS FOR [illegible]
STUART LAKE [illegible]

	1ST SAMPLING ([illegible])				2ND SAMPLING ([illegible])				3RD SAMPLING ([illegible])			
	4 SITES				4 SITES				4 SITES			
[illegible]	[illegible]		[illegible]	[illegible]	[illegible]		[illegible]	[illegible]	[illegible]		[illegible]	[illegible]
TEMP (C)	12.0	- 15.4	13.7	13.1	19.0	- 25.5	21.3	20.7	25.7	- 25.9	25.8	25.8
[illegible]	7.2	- 10.2	8.5	8.7	3.1	- 9.7	6.0	7.1	1.0	- 8.6	6.3	5.4
[illegible]	136.	- 178.	158.	154.	115.	- 233.	161.	178.	225.	- 235.	231.	230.
PH (STAND UNITS)	7.0	- 8.4	7.6	7.6	7.3	- 8.0	8.1	8.1	7.1	- 8.3	7.6	7.6
TOT ALK (MG/L)	65.	- 74.	72.	72.	74.	- 98.	74.	78.	[illegible]			
TOT P (MG/L)	0.025	- 0.131	0.058	0.078	0.025	- 0.132	0.059	0.071	[illegible]			
ORTHO P (MG/L)	0.007	- 0.052	0.013	0.018	0.004	- 0.032	0.015	0.013	[illegible]			
NO2+NO3 (MG/L)	0.035	- 0.596	0.301	0.346	0.078	- 0.786	0.274	0.254	[illegible]			
AMMONIA (MG/L)	0.031	- 0.068	0.044	0.048	0.023	- 0.098	0.044	0.046	[illegible]			
KJEL N (MG/L)	0.488	- 0.488	0.541	0.685	0.485	- 0.491	0.578	0.673	[illegible]			
INORG N (MG/L)	0.070	- 0.108	0.138	0.066	0.108	- 0.429	0.384	0.296	[illegible]			
TOTAL N (MG/L)	0.488	- 0.488	0.694	0.838	0.578	- 0.388	0.452	0.738	[illegible]			
CHLOPHYL A (UG/L)	1.0	- 24.0	10.1	9.1	1.0	- 21.0	14.0	11.0	23.0	- 50.0	38.3	35.0
SECCHI METERS	0.3	- 1.0	0.7	1.0	0.3	- 1.0	0.5	0.6	0.5	- 1.0	1.0	1.0

[illegible] SUMMARY OF [illegible] IN CHEMICAL CHARACTERISTICS FOR TAMPON CREEK
[illegible]

[illegible] SAMPLING [illegible]

PARAMETER	[illegible] SITES RANGE	MEAN	MEDIAN
TEMP (C)	20.3 - 21.7	20.9	20.7
DISS OXY (MG/L)	5.8 - 8.8	7.1	7.0
CONDCTVY (MICROMHO)	150. - 160.	154.	155.
PH (STAND UNITS)	7.0 - 8.0	7.5	7.6
TOT ALK (MG/L)	78. - 95.	84.	84.
TOT P (MG/L)	0.031 - 0.047	0.039	0.040
ORTHO P (MG/L)	0.018 - 0.037	0.032	0.028
NO2+NO3 (MG/L)	0.028 - 0.078	0.047	0.038
AMMONIA (MG/L)	0.020 - 0.078	0.045	0.050
KJEL N (MG/L)	0.280 - 0.480	0.417	0.405
INORG N (MG/L)	0.060 - 0.540	0.122	0.060
TOTAL N (MG/L)	[illegible] - 0.720	0.505	0.405
CHLOPYL A (UG/L)	4.3 - 34.2	20.1	15.3
SECCHI (METERS)	0.5 - 1.1	0.9	0.9

B. Biological characteristics:

1. Phytoplankton -

Sampling Date	Station Number		Chlorophyll a (ug/l)
01/09/74	1.	Melosira sp.	5,861
	2.	Stephanodiscus sp.	624
	3.	Nitzschia sp.	567
	4.	Cryptomonas sp.	551
	5.	Chroomonas sp.	441
		Other genera	1,299
		total	9,363
06/11/74	1.	Stephanodiscus sp.	956
	2.	Melosira sp.	665
	3.	Kirchneriella sp.	541
	4.	Scenedesmus sp.	540
	5.	Chroomonas sp.	499
		Other genera	1,747
		total	4,948
08/12/74	1.	Oscillatoria sp.	2,750
	2.	Nitzschia sp.	2,750
	3.	Merismopedia sp.	1,650
	4.	Lyngbya sp.	1,250
	5.	Melosira sp.	1,200
		Other genera	6,152
		total	15,652
11/01/74	1.	Oscillatoria sp.	359
	2.	Pennate Diatoms	326
	3.	Dactylococcopsis sp.	196
	4.	Merismopedia sp.	196
	5.	Melosira sp.	163
		Other genera	510
		total	1,730

B. Chlorophyll a -

Sampling Date	Station Number	Chlorophyll a (ug/l)
03/09/74	1	5.8
	2	5.8
	3	6.2
	4	10.1
	5	11.0
	6	24.0
05/17/74	1	1.4
	2	6.4
	3	11.0
	4	12.9
	5	24.1
	6	28.5
08/12/74	1	61.2
	2	24.8
	3	29.6
	4	23.5
	5	40.4
	6	50.6
11/01/74	1	4.3
	2	9.2
	3	12.3
	4	11.3
	5	14.2
	6	9.3

C. Limiting Nutrient Study:

A 50% loss of phosphorus occurred in the assay samples during shipment from the field to the laboratory, and the algal assay results are not representative of conditions in the lake at the time the samples were taken (11/01/74).

The lake data indicate a temporal and spatial combination of limiting nutrients. Following is a tabulation of the mean inorganic nitrogen/orthophosphorus ratios for each of the sampling stations and times with the indicated limiting nutrient in parentheses.

Station	03/11/74	05/17/74	11/01/74
1	11/1 (N)	18/1 (P)	10/1 (N)
2	9/1 (N)	25/1 (P)	6/1 (N)
3	12/1 (N)	25/1 (P)	2/1 (N)
4	8/1 (N)	19/1 (P)	5/1 (N)
5	5/1 (N)	10/1 (N)	2/1 (N)
6	8/1 (N)	22/1 (P)	3/1 (N)

IV. NUTRIENT LOADINGS
(See Appendix E for data)

For the determination of nutrient loadings, the Texas National Guard collected monthly near-surface grab samples from each of the tributary sites indicated on the map (page vi), except for the month of June when two samples were collected. Sampling was begun in September, 1974, and was completed in August, 1975.

Through an interagency agreement, stream flow estimates for the year of sampling and a "normalized" or average year were provided by the Texas District Office of the U.S. Geological Survey for the tributary sites nearest the lake, except for the South Fork of the Sabine River (station D-1). The drainage area of this stream and the flow (mean of 15 years) were obtained from U.S.G.S. records (Anonymous, 1975).

Except for the South Fork, nutrient loads in sampled tributaries were determined by using a modification of a U.S. Geological Survey computer for calculating stream loadings[a]. The nutrient loads in the South Fork were calculated using mean concentrations and the mean flow. Also, the nutrient loads in the water diverted by the Sabine River Authority were calculated using the mean nutrient concentrations at lake sampling station 1 and the mean diversion flow (Gray, 1976). Nutrient loads shown are those measured minus point-source loads, if any.

Nutrient loads for unsampled "minor tributaries and immediate drainage" ("ZZ" of U.S.G.S.) were estimated using the adjusted nutrient

[a] See Working Paper No. 175.

loads at station B-1, in kg/km²/year, and multiplying by the ZZ area in km².

The operators of the Caddo Mills, Celeste, Greenville, Quinlan, Royse City, and Wind Point Park wastewater treatment plants provided monthly effluent samples and corresponding flow data.

Four additional municipal wastewater treatment plants, with a combined effluent flow of 268 m³/day, discharged in the drainage during the sampling year; however, these plants do not significantly influence the quality of the receiving streams and probably have little effect on the lake (Anonymous, 1974[?]).

A. Waste Sources:

1. Known municipal* -

Name	Pop. Served	Treatment	Mean Flow (m^3/d)	Receiving Water
Caddo Mills	1,100	stab. pond	214.4	West Caddo Creek
Celeste	746	stab. pond	265.0	Cowleech Fork
Greenville	24,000	tr. filter + pond	8,842.1	Cowleech Fork
Quinlan	844	act. sludge	486.8	Nufals Branch/ Jones Creek
Royse City	2,000	oxid. ditch	561.9	Pond Creek/ S. Fk., Sabine River
Wind Point Park	vari-able**	ext. aer.	5.6	Lake Tawakoni

2. Known industrial - None

* Treatment plant questionnaires.
** Park use varies from year to year.

B. Annual Total Phosphorus Loading - Average Year:

1. Inputs -

Source	kg P/ yr	% of total
a. Tributaries (non-point load) -		
Caddo Creek	11,670	8.7
Cowleech Fork	61,115	45.4
South Fork	9,870	7.3
b. Minor tributaries & immediate drainage (non-point load) -	17,275	12.8
c. Known municipal STP's -		
Caddo Mills	345	0.3
Celeste	460	0.4
Greenville	28,115	20.9
Quinlan	1,475	1.1
Royse City	1,750	1.3
Wind Point Park	30	0.1
d. Septic tanks - Unknown	?	-
e. Known industrial - None	-	-
f. Direct precipitation* -	2,600	1.9
Total	134,705	100.0

2. Outputs -

Lake outlets -	Diversions	1,190
	Sabine River	14,960
	Total	16,150

3. Net annual P accumulation - 118,305 kg.

* See Working Paper No. 175.

C. Annual Total Nitrogen Loading - Average Year:

1. Inputs -

Source	kg N/ yr	% of total
a. Tributaries (non-point load) -		
Caddo Creek	105,920	11.3
Cowleech Fork	347,775	37.0
South Fork	104,805	11.2
b. Minor tributaries & immediate drainage (non-point load) -	157,710	16.8
c. Known municipal STP's -		
Caddo Mills	650	0.1
Celeste	910	0.1
Greenville	54,730	5.8
Quinlan	3,050	0.3
Royse City	3,020	0.3
Wind Point Park	105	<0.1
d. Septic tanks - Unknown	?	-
e. Known industrial - None	-	-
f. Direct precipitation* -	160,350	17.1
Total	939,115	100.0

2. Outputs -

Lake outlets -	Diversions	22,730
	Sabine River	252,140
	Total	274,870

3. Net annual N accumulation - 664,245 kg.

* See Working Paper No. 175.

D. Non-point Nutrient Export by Subdrainage Area:

Tributary	kg P/km²/yr	kg N/km²/yr
Caddo Creek	21	210
Cowleech Fork	175	995
South Fork	48	515

E. Yearly Loads:

In the following table, the existing phosphorus loadings are compared to those proposed by Vollenweider (Vollenweider and Dillon, 1974). Essentially, his "dangerous" loading is one at which the receiving water would become eutrophic or remain eutrophic; his "permissible" loading is that which would result in the receiving water remaining oligotrophic or becoming oligotrophic if morphometry permitted. A mesotrophic loading would be considered one between "dangerous" and "permissible".

Note that Vollenweider's model may not be applicable to water bodies with short hydraulic retention times.

	Total Phosphorus		Total Nitrogen	
	Total	Accumulated	Total	Accumulated
grams/m²/yr	0.91	0.80	4.3	4.5

Vollenweider phosphorus loadings (g/m²/yr) based on mean depth and mean hydraulic retention time of Lake Tawakoni:

"Dangerous" (eutrophic loading)	0.10
"Permissible" (oligotrophic loading)	0.15

V. LITERATURE REVIEWED

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VI. APPENDICES

APPENDIX A

LAKE RANKINGS

LAKE DATA TO BE USED IN RANKINGS

LAKE CODE	LAKE NAME	[illegible] TOTAL *	[illegible] INDEX *	[illegible] MEAN SIZ	[illegible] CAPACA	[illegible] [illegible]	[illegible] 1000 [illegible] *
[illegible]	[illegible] LAKE	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible] LAKE	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible] RESERVOIR	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible] LAKE	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible] LAKE	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	LAKE [illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible] LAKE	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible] LAKE	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible] RESERVOIR	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	LAKE [illegible] CITY	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible] [illegible] LAKE	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible] LAKE	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible] [illegible] LAKE	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible] LITTLE [illegible] RESERVO	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible] LAKE	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible] LAKE	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	LAKE OF THE PINES	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible] RESERVOIR	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible] LAKE	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible] & [illegible] LAKE	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible] LAKE	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	LAKE [illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible] LAKE	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible] [illegible] RESERVOIR	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible] [illegible] RESERVOIR	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible] [illegible] [illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	E [illegible] SPRINGS RESERVOIR	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

[illegible] RANKED BY INDEX VAL.

RANK	LAKE CODE	LAKE NAME	INDEX VAL.
1	[illegible]	[illegible]	[illegible]
2	[illegible]	[illegible]	[illegible]
3	[illegible]	[illegible]	[illegible]
4	[illegible]	[illegible]	[illegible]
5	[illegible]	[illegible]	[illegible]
6	[illegible]	[illegible]	[illegible]
7	[illegible]	[illegible]	[illegible]
8	[illegible]	[illegible]	[illegible]
9	[illegible]	[illegible]	[illegible]
10	[illegible]	[illegible]	[illegible]
11	[illegible]	[illegible]	[illegible]
12	[illegible]	[illegible]	[illegible]
13	[illegible]	[illegible]	[illegible]
14	[illegible]	[illegible]	[illegible]
15	[illegible]	[illegible]	[illegible]
16	[illegible]	[illegible]	[illegible]
17	[illegible]	[illegible]	[illegible]
18	[illegible]	[illegible]	[illegible]
19	[illegible]	[illegible]	[illegible]
20	[illegible]	[illegible]	[illegible]
21	[illegible]	[illegible]	[illegible]
22	[illegible]	[illegible]	[illegible]
23	[illegible]	[illegible]	[illegible]
24	[illegible]	[illegible]	[illegible]
25	[illegible]	[illegible]	[illegible]
26	[illegible]	[illegible]	[illegible]
27	[illegible]	[illegible]	[illegible]
28	[illegible]	[illegible]	[illegible]

LAKES RANKED BY INDEX NO.

RANK	LAKE CODE	LAKE NAME	INDEX NO.
29	4421	LYNDON B JOHNSON LAKE	230
30	4424	TEXOMA LAKE	217
31	4425	SOMERVILLE LAKE	206
32	4426	SAN ANGELO RESERVOIR	186
33	4433	TEXARKANA LAKE	176
34	4435	GARZA LITTLE ELM RESERVOIR	173
35	4438	TRINIDAD	169
36	4439	BRYANS LAKE	159
37	4441	CORPUS CHRISTI LAKE	155
38	4447	HOUSTON LAKE	139
39	4448	LIVINGSTON LAKE	91

PERCENT OF LAKES WITH HIGHER VALUES; NUMBER OF LAKES WITH HIGHER VALUES

LAKE CODE	LAKE NAME	TOTAL P	INORG N	PLUS CC	CHLOR A	SD	DISS ORTHO P	INDEX NO
4429	SOMERVILLE LAKE	29 (11)	55 (21)	24 (9)	3 (1)	67 (25)	38 (10)	259
4438	STAMFORD LAKE	18 (7)	47 (17)	5 (2)	18 (7)	62 (31)	39 (14)	254
4431	STILLHOUSE HOLLOW RESERV	68 (23)	37 (14)	67 (23)	42 (15)	17 (6)	51 (19)	312
4432	TAWAKONI LAKE	32 (12)	78 (29)	37 (14)	21 (8)	63 (24)	38 (10)	253
4433	TEXOMA LAKE	11 (4)	51 (19)	13 (5)	16 (6)	72 (27)	13 (5)	179
4434	TEXOMA LAKE	39 (14)	34 (13)	61 (23)	45 (17)	17 (8)	21 (7)	217
4435	TRAVIS LAKE	68 (33)	21 (7)	42 (15)	62 (33)	17 (8)	54 (21)	264
4436	TWIN BUTTES	0 (0)	61 (22)	11 (4)	5 (2)	42 (15)	0 (0)	169
4437	TWIN BUTTES RESERVOIR	59 (22)	21 (7)	58 (22)	61 (23)	49 (17)	63 (23)	311
4438	WHITE HORSE RESERVOIR	54 (32)	61 (22)	76 (29)	69 (34)	17 (8)	62 (23)	379
4439	WHITNEY LAKE	62 (24)	51 (19)	79 (30)	71 (27)	17 (8)	76 (29)	357

APPENDIX B

CONVERSION FACTORS

CONVERSION FACTORS

Hectares x 2.471 = acres

Kilometers x 0.6214 = miles

Meters x 3.281 = feet

Cubic meters x 8.107×10^{-4} = acre/feet

Square kilometers x 0.3861 = square miles

Cubic meters/ sec x 35.315 = cubic feet/sec

Centimeters x 0.3937 = inches

Kilograms x 2.205 = pounds

Kilograms/square kilometer x 5.711 = lbs/square mile

APPENDIX C

TRIBUTARY FLOW DATA

APPENDIX D

PHYSICAL and CHEMICAL DATA

[illegible]

| | | |

[illegible]

[illegible]
[illegible]
[illegible]
[illegible]

[illegible]

DATE	TIME	DEPTH	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
FROM	OF		WATER	DO	TRANSP	CNDUCTVY	PH	T ALK	[illegible]	TOT HARD	[illegible]	[illegible]
TO	DAY	FEET	CENT	MG/L	SECCHI	FIELD	SU	MG/L	MG/L	MG/L	MG/L	MG/L
					INCHES	MICROMHS		CACO3	TOTAL	Ca	TOTAL	DISS
74/03/11	11	10	[illegible]	[illegible]		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
	11	30	[illegible]	16.9	6.2		7.45	71	[illegible]	[illegible]	[illegible]	[illegible]
	11	50	[illegible]	17.3	7.2		7.69	73	[illegible]	[illegible]	[illegible]	[illegible]
74/05/17	15	10	[illegible]	25.4		15	7.85	66	[illegible]	[illegible]	[illegible]	[illegible]
	15	30	[illegible]	26.4	6.6		7.86	66	[illegible]	[illegible]	[illegible]	[illegible]
	15	50	[illegible]	25.9	6.6		7.75	61	[illegible]	[illegible]	[illegible]	[illegible]
74/08/12	13	50	[illegible]	29.7	6.6	24	7.88					
	13	50	[illegible]	29.6	7.6		7.88					
74/11/01	10	45	[illegible]	21.7	8.8	29	7.99	91	[illegible]	[illegible]	[illegible]	[illegible]
	10	45	[illegible]	21.4	7.6		7.82	92	[illegible]	[illegible]	[illegible]	[illegible]
	10	45	[illegible]	21.7	7.4		7.84	49	[illegible]	[illegible]	[illegible]	[illegible]

DATE	TIME	DEPTH	[illegible]	[illegible]	[illegible]
FROM	OF		[illegible]	[illegible]	[illegible]
TO	DAY	FEET	MG/L P	MG/L	[illegible]
74/03/11	11	10	[illegible]	11.8	
	11	30	[illegible]		
	11	50	[illegible]		
74/05/17	15	10	[illegible]	24.1	
	15	30	[illegible]		
	15	50	[illegible]		
74/08/12	13	50	[illegible]	46.9	
	13	50	[illegible]		1.6
74/11/01	10	45	[illegible]	14.2	
	10	45	[illegible]		
	10	45	[illegible]		

[illegible]
[illegible]

STORET 4[illegible] DATE 79/02/11

[illegible]
43 55 36.0 048 04 20.0
TAMPUKI LAKE
[illegible] T0485

[illegible]

DATE	TIME	DEPTH	00010	00300	00077	00094	00400	00410	00415	00425	00428	00671
FROM	OF		WATER	DO	TRANSP	CNDUCTVY	PH	T ALK	HRDNS	TOT +DEL	HARDNESS	PHOS-DIS
TO	DAY	FEET	CENT	MG/L	SECCHI	FIELD	SU	CACO3	TOTAL	N	NONCARB	ORTHO
					INCHES	MICROMHO		MG/L	MG/L	MG/L	MG/L	MG/L P
79/01/11	12	27	0001	11.1	9.3	12	144	6.45	72	0.245	0.700	0.014
	12	00	0004	17.0	8.6		185	7.45	72	0.244	0.488	0.008
79/05/17	15	30	0006	26.5		10	233	8.48	90	0.256	0.988	0.598
	15	30	0007	26.5	7.6		229	8.50	90	0.249	0.780	0.498
79/09/12	11	30	0009	26.3	7.0	10	231	8.22				
	11	30	0007	26.3	6.9		231	8.24				
79/11/01	11	40	0008	21.5	9.0	10	199	7.48	65	0.250	0.468	0.006
	11	50	0005	20.7	5.8		196	7.42	61	0.271	0.480	0.445
	11	70	0011	20.6	5.2		194	7.04	67	0.270	0.488	0.478

DATE	TIME	DEPTH	00945	32217	99111
			CHLORIDE	CHLOROPHYL	INCST LT
FROM	OF			A	PENETRA
TO	DAY	FEET	MG/L	UG/L	PERCENT
79/03/11	12	00	0002	0.672	24.0
	12	00	0004	0.655	
79/05/17	15	30	0005	0.132	26.5
	15	30	0007	0.099	
79/09/12	11	30	0009		58.6
79/11/01	11	50	0002	0.096	6.3
	11	50	0004	0.243	
	11	50	0011	0.247	

APPENDIX I

TRIBUTARY AND WASTEWATER TREATMENT PLANT DATA

[illegible]

[illegible]
32 5= 35.0 096 09 38.0 =
[illegible]
=0 15 [illegible]
[illegible]
[illegible] 45 =035 2.4 =[illegible]
[illegible] [illegible]
[illegible]

DATE	TIME	DEPTH	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
FROM	OF		[illegible]	TOT KJEL	[illegible]	PHOS-DIS	PHOS-TOT
TO	DAY	FEET	MG/L	N	TOTAL	DRIED	MG/L P
				MG/L	MG/L	MG/L P	
[illegible]	16	20	[illegible]	1.100	[illegible]	[illegible]	[illegible]
74/10/07	14	25	0.886	0.480	0.015	0.098	0.110
74/11/06	11	30	0.832	1.000	0.038	0.135	0.186
74/12/06	13	30	[illegible]	2.200	0.094	0.120	0.560
75/01/13	12	55	1.810	1.060	0.024	0.056	[illegible]
75/02/14	13	35	[illegible]	0.700	[illegible]	[illegible]	[illegible]
75/03/07	12	30	0.805	1.250	0.095	0.035	0.090
75/04/11	11	50	1.600	1.400	0.070	2.190	0.300
75/05/13	11	35	0.490	0.700	0.045	0.095	0.140
75/06/04	12	30	1.400	0.950	0.050	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
75/10/16	14	55	0.810	0.900	0.040	0.075	0.110
75/09/27	12	30	0.895	0.500	0.040	0.045	0.106

[illegible]

[illegible]
[illegible]
[illegible]
[illegible]
[illegible]
[illegible]

DATE	TIME	DEPTH	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
FROM	OF		N-TOTAL	N	TOTAL	[illegible]	
TO	DAY	FEET	MG/L	MG/L	MG/L	MG/L P	MG/L P
[illegible]	[illegible]	30	1.516	1.784	4.270	1.246	1.570
[illegible]	13	45	1.668	1.968	3.925		
[illegible]	10	45	0.776	1.388	8.125	0.788	0.738
[illegible]	11	15	0.128	1.456	8.696	0.184	0.488
[illegible]	10	45	1.836	2.485	1.196	1.296	1.438
[illegible]	11	15	1.352	2.528	1.852	1.252	1.282
[illegible]	10	45	2.386	3.988	1.788	2.386	2.786
[illegible]	11	18	1.158	1.558	8.246	0.398	0.688
[illegible]	10	48	1.488	2.258	1.888	1.256	1.186
[illegible]	11	25	1.358	1.188	8.185	0.746	0.946
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	14	35	0.862	1.185	2.488	2.758	3.188
[illegible]	11	38	0.386	1.888	2.188	2.756	3.188

[illegible]

[illegible]
32 to 15.0 [illegible] to 57.0 -
[illegible]
40 15 [illegible]
[illegible]
[illegible] [illegible] [illegible] [illegible] [illegible] [illegible] [illegible]
[illegible] [illegible]
[illegible] [illegible] [illegible] [illegible]

DATE	TIME	DEPTH	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
FROM	OF		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
TO	DAY	FEET	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

[illegible] STREET <TRIBAL DATE 76/05/13

[illegible]
32 07 35.0 096 04 05.0 4
[illegible]VILLE
48 7.5 DRESSLAND <48
[illegible]MON LAKE [illegible]
[illegible]LEED> FISH SABINE <DNR>
[illegible]EPALES 25x125>
[illegible] FEET DEPTH CLASS 00

DATE	TIME	DEPTH	00630 NITRATE TOTAL	00625 TOT KJEL N	39510 MICRO TOTAL	00671 PHOS-DIS ORTHO	00665 PHOS-TOT P	50051 FLOW RATE	34053 CONDUCT FLD@25C
FROM	DF								
TO	DAY	FEET	MG/L	MG/L	MG/L	MG/L P	MG/L P	CFS	UMHO/CM
74/10/[illegible]	09	00							
DP(T)-			0.360	15.000	3.896		5.000	3.000	2.300
74/10/24	24	00							
74/10/30	00	00							
DP(T)-			0.240	13.750	3.430	0.000	5.050	1.040	1.700
74/10/30	17	00							
74/11/27	00	00							
DP(T)-								1.470	2.440
74/11/27	24	00							
74/12/25	00	00							
DP(T)-			0.740	14.000	3.400	7.700	7.200	2.400	2.400
74/12/26	17	00							
75/01/22	00	00							
DP(T)-			0.000	25.000			9.900	2.070	2.400
75/01/22	24	00							
75/02/19	00	00							
DP(T)-			0.260	18.000	7.175	9.400	9.300	1.300	2.750
75/02/19	24	00							
75/03/19	00	00							
DP(T)-			0.000	14.000	3.300	6.000	7.100	2.500	1.450
75/03/19	16	00							
75/04/17	00	00							
DP(T)-			0.050	12.300	1.300	5.400	6.400	1.470	1.900
75/04/17	00	00							
75/05/15	24	00	0.050	10.500	4.300	7.400	10.500	5.740	2.530
75/06/25	15	30	0.175	17.000	5.050	1.000	10.000	2.090	2.700
75/07/24	15	30	0.050	10.500	1.000	6.700	9.400	2.220	2.100
75/08/21	15	30	0.375	14.000	1.700	7.300	9.100	2.150	2.170
75/09/18	15	00	0.475	25.000	3.100	0.400	10.500	1.950	2.050

[illegible]

[illegible] WATER RESOURCES DATA [illegible]

[illegible]
[illegible]
[illegible]
[illegible]
[illegible]
[illegible]
[illegible]

DATE	TIME	DEPTH	00035	00075	00010	00071	00065	54851	54853
FROM	OF		WEATHER	TOT FUEL	WATER	PHOS-DIS	PHOS-TOT	FLOW	[illegible]
TO	DAY	FEET	CODE	%	TOTAL	UNITS		RATE	[illegible]
				MG/L	°/L	MG/L P	MG/L P	[illegible]	[illegible]
[illegible]									
74/10/21	09	45		0.490	9.490	0.0500	3.200	2.950	0.052	0.053
74/11/15	09	20		0.400	9.000	0.0500	3.500	[illegible]	0.052	0.056
74/12/16	09	30		1.120	9.000	0.140	3.600	[illegible]	0.052	0.070
75/01/15	10	00		1.200	9.000	0.310	3.400	[illegible]	0.052	0.070
75/02/20	09	30		1.300	5.470	0.250	5.450	7.250	0.051	0.060
75/03/21	10	15		1.300	11.300	0.130	[illegible]	6.700	0.052	0.060
75/04/24	09	45		0.600	10.500	0.140	[illegible]	5.900	0.052	0.055
75/05/19	09	10		0.250	5.000	0.0500	3.425	[illegible]	0.052	0.055
75/06/27	10	20		0.075	10.200	0.025	2.300	2.050	0.052	0.060
[illegible]				[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
75/09/29	13	45		0.050	15.000	0.050	3.500	5.300	0.052	0.052

[illegible]

A VALUE KNOWN TO BE
LESS THAN INDICATED

[illegible]

[illegible]

DATE	TIME	DEPTH	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
FROM	OF		[illegible]	N	TOTAL	[illegible]		FLOW	[illegible]
TO	DAY	FEET	MG/L	MG/L	MG/L	MG/L P	MG/L P	RATE	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

[illegible]
[illegible]

[illegible]

DATE	TIME	DEPTH	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
FROM	TO		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

[illegible]
[illegible]